

# Appendix A

## Phosphorus and Lake Water Quality

### **The Relationship Between Phosphorus and Lake Water Quality**

Lakes are biological systems that are clearly affected by changes in water quality. They are most noticeably affected by an increase in nutrients, particularly phosphorus. Increases in phosphorus usually result in more noticeable changes to water quality than increases in other nutrients. Algae, which are microscopic plants common in lakes, need phosphorus in order to grow. Consequently, when phosphorus is abundant in lake water, algal populations soar in number, causing a decline in water transparency. In some cases, algal blooms may occur causing the growth of billions of algae to color the lake water green and release strong odors as they decay.

Beyond the aesthetic impacts, algal blooms have serious impacts on a lake's biological community. Through a complex chain of events, algal blooms lead to depletion of the lake water's oxygen supply, usually resulting in the eventual loss of trout and salmon (cold water) fisheries. In addition, large algal populations cause odor, taste, and treatment problems in lakes used for public water supplies.

The biological term for the process described above is eutrophication - the gradual increase in nutrient inputs to a lake over time. Lake eutrophication can be dramatically accelerated by human activities, causing the noticeable changes described above in a relatively short period of time. Many lakes in Maine have already experienced dramatic declines in water quality as a result of human disturbances.

### **How Phosphorus Gets into Lakes**

Understanding how phosphorus gets into lake water requires an understanding of where lake water comes from. Precipitation and stormwater runoff are significant sources of water in rivers and lakes. Rain and melting snow flow downhill over the land surface into streams and lakes or seep into the ground becoming groundwater, which also ultimately discharges to streams and lakes.

The land area that contributes water to a particular lake is known as its watershed. Watershed boundaries can be identified by connecting points of highest elevation around a lake and its tributaries. All rain and snow falling within this area eventually flow by gravity in surface runoff, streams, and groundwater to the lake, which is the lowest point in the watershed.

The quality of water in a lake depends on the condition of the land in its watershed. Phosphorus is abundant in the environment, but in an undisturbed environment it is tightly bound up by soil and organic matter for eventual use by plants. Natural systems conserve and recycle nutrients, water, and other materials needed to sustain plant growth. Water is stored in depressions on the uneven forest floor and seeps into the ground to become groundwater, thereby preventing it from running over the land surface and exporting valuable nutrients from the system.

Land development changes the natural landscape in ways that alter the normally tight cycling of phosphorus. The removal of vegetation, smoothing of the land surface, compaction of soils, and creation of impervious surface combine to reduce the amount of precipitation stored and retained on-site, dramatically increasing the amount of water running off the land as surface runoff.

These changes to the land surface and the associated increase in surface runoff dramatically increase phosphorus export. Land disturbance upsets the environment's ability to retain phosphorus. Stormwater flowing over the land surface picks up phosphorus and transports it in soluble form or attached to eroded soil particles. The phosphorus in stormwater comes from natural and human sources, including eroded soil, road dust, plants, lawn fertilizer and detergents. The smooth surfaces, closely cropped lawns, and compacted soils common in developed areas do not retain phosphorus, and only speed its removal by generating surface runoff. The end result is more phosphorus in stormwater, and thus more phosphorus in lakes.

A study in Maine has documented the elevated levels of phosphorus exported from developed land (Dennis, 1985). In adjacent watersheds, one developed and one undisturbed, phosphorus export from the developed watershed was up to 10 times greater than the export from the forested watershed. Because the built watershed was developed years ago, these figures represent the permanent increase in phosphorus export caused by alteration of the landscape. This permanent increase in the phosphorus supply of the lake creates an equally permanent and irreversible decline in water quality.

Though in most lakes the majority of phosphorus comes from the watershed, there is another source of phosphorus that can be very significant in some lakes. Over the centuries phosphorus rich organic sediments have accumulated on the bottom of our lakes. In most cases, the phosphorus in these sediments is trapped there by a blanket of iron hydroxide and or aluminum hydroxide, which makes the sediments a sink for, rather than a source of, phosphorus. However, in lakes with sufficient algal production to cause a severe loss of oxygen concentrations above the sediments, the iron hydroxide blanket dissolves and large amounts of phosphorus may be recycled into the lake water. The "surges" of phosphorus feed algal growth which further depletes dissolved oxygen, thus creating a vicious cycle of very rapid, internally driven eutrophication. This process, which can be initially triggered by relatively small increases in phosphorus input from the watershed, may drive a lake from apparently good, clear water quality to having intense algal blooms in a matter of years. It is particularly important to limit any increases in phosphorus input from the watershed to lakes with a high potential for sediment phosphorus recycling.

## **How Stormwater Phosphorus Can be Controlled**

All land disturbance and development in a lake's watershed increases phosphorus export to a lake. Although some increase must be accepted as the inevitable and unavoidable effect of development, a variety of measures can substantially reduce phosphorus export to lakes and help to preserve good water quality.

The simplest way to reduce phosphorus export is to limit clearing of vegetation and minimize the area developed, especially road length. Beyond this, a variety of control measures are available. They generally focus on detaining and storing stormwater where it can be treated and released or infiltrated into the soil.

Buffer areas are naturally vegetated areas preserved downslope of developed areas. These buffers intercept and store surface runoff, allowing it to infiltrate rather than flow off-site as surface flow.

Infiltration systems are more sophisticated. Runoff is collected from rooftops, driveways and/or impervious parts of a lot and then directed to surface or underground storage, similar to a subsurface wastewater disposal area, from which it infiltrates into the soil. Soils must be fairly deep, coarse, and permeable for infiltration systems to work.

Underdrained soil filters are similar to infiltration systems in that runoff is collected and directed to a storage depression, but the depression is vegetated with flood and drought tolerant species and is lined with a specific soil filter media which is underlain with a pipe system to discharge the filtered runoff.

Wet ponds are generally used to treat runoff from a large area. They receive and retain stormwater from large drainage areas, allowing sediment to settle out and dissolve phosphorus to be removed by biological activity.

Development can proceed in lake watersheds without generating more phosphorus than the lake can tolerate by limiting the extent of development and incorporating one or more of these phosphorus controls. Once a lake has accepted more phosphorus than it can tolerate, there will be a noticeable decline in water quality.